USING DATA LOGGERS IN THE FIELD

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ABSTRACT

This manual is a guide for the use of electronic data loggers in an environmental monitoring programme. The basic principles of data collection, the problems that can be encountered, and approaches to avoid these problems are presented. The manual is oriented to the Campbell Scientific Inc. CR21, CR10, and 21X data loggers. Topics covered include the installation, operation, and maintenance of data loggers; and the retrieval and determination of the accuracy of the data.

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1 INTRODUCTION

This publication is a guide of the use of electronic data loggers in an environmental monitoring programme. It is oriented to the use of data loggers in "hostile" environments, that is, without A.C. power and climate-controlled facilities. The basic principles of data collection, the problems that can be encountered, and approaches to avoid these problems are presented. Although this manual focuses on the Campbell Scientific Inc. CR21, CR10 and 21X data loggers, the basic principles for the careful operation of other data loggers are the same.

This publication does not consider the interrogation of data loggers via telephone or telemetry; nor does it explain how a data logger should be programmed, which sensors to use or how sensors work. You will have to **READ THE MANUALS PROVIDED WITH THE EQUIPMENT** for this information.

The material presented here is based on my own experiences and those of other researchers. The aim of this manual is to help other researchers avoid the errors we made. Readers should note that almost all of the problems encountered during data logger use are the result of operator error (carelessness or ignorance), or damage to a sensor or cable. As long as the data logger is protected from extreme environmental conditions, there is little risk of data logger failure.

Many of the points made may seem obvious. However, even experienced researchers can make simple mistakes. There is a certain amount of repetition in this manual. This is intended to minimize cross-referencing between sections. Examples of blank and filled-in input and output program forms, computer file record forms, and log sheets are presented in the Appendices. Please contact me if you have any problems in using this manual, or tips on data logger operation that you would like to pass on to other users.

2 BASIC CONSIDERATIONS IN DATA COLLECTION

There are a number of steps that should be followed in any environmental monitoring programme using data loggers. I am assuming that you have already chosen a suitable site.

2.1 Planning the Data Collection Programme

The first thing to decide is what you want to get out of the measurements: that is, the end use of the data. It is easy to collect lots of data from many sensors, and, although you should avoid amassing superfluous data, it is better to err on the side of too much than too little.

a. Selection of sensors: Many different sensors are readily available, but you may still require some to be custom designed with respect to lead length.

b. Selection of the sampling frequency: This depends on the time response of the sensor, the frequency of change of the variables being monitored and the end use of the data. Many weather variables require sampling at frequencies of between 1 second and 1 minute.

c. Selection of the recording frequency: This again depends on the variability of the factors under investigation and the end use of the data. Daily summaries - e.g., maximums, minimums and averages (temperature, wind speed); totals (solar radiation, rainfall); spot readings (moisture blocks) - may be sufficient for most studies. A few days of half-hourly readings may be enough to describe typical diurnal trends. Include a daily summary output table when you record on a shorter time period.

d. Selection of servicing frequency of the data logger: Servicing is required to check that the logger is working, to collect the recorded data, and to change the batteries. Size of battery, power consumption (Section 4.4), and the number of data points required to fill data logger or storage module memory (Section 3.2) control the number of days the logger can be operated without servicing. Radio telemetry, solar powered batteries, storage modules, and tape recorders can be used to reduce the frequency of visits to the site.

e. Determine a schedule for sensor servicing and calibration.

f. Selection of service technician: Determine who will service the data logger, how much they need to know, and what procedures they should follow.

g. Archiving and analysing the data: A procedure for editing, labelling, and archiving the information collected should be chosen at the start of the data collection programme. Similarly, the type of analysis to be performed on the data should be considered so that it can be collected and stored appropriately.

2.2 Data Record Identification

With all the numbers that can be collected by data loggers, it is easy to get the files confused, particularly when more than one data logger is used.

a. Include the data logger serial number or some other identification number in the output using the fixed data command. This will help you identify unlabelled cassette tapes and computer files.

b. Julian day and time should be output for each recording period. Record the battery voltage and panel temperature (CR10 and 21X) on each day's summary output. The program signature can be recorded to indicate when changes are made to the program.

c. Each data record on a cassette tape should be labelled with a vocal record of location, date, time, data logger, and operator.

d. Maintain log sheets, indicating such items as operations performed at site visits, problems encountered, program changes, and weather conditions.

2.3 Back-up Measurements

Do not rely on 100% data capture with the logger. There are a number of ways that the data can be lost, particularly through operator error. Measuring some of the variables by other means is recommended. There should be a storage rain gauge to back-up rainfall, and a thermograph and maximum and minimum thermometers in a Stevenson's screen for air temperature.

2.4 Servicing the Data Logger

Draw up a check list of items needed during a site visit and make sure that you have them before leaving the office. The reliability of the data record should be checked at each site visit.

a. A service kit should include tape recorder and tape, tool kit (e.g., screwdriver, pliers, butane-powered soldering iron, and solder), spare cable, multimeter, logger and sensor manuals, program, Assmann or sling psychrometer (with water), and the cables to connect the computer and tape recorder to the data logger.

b. Check that the data logger time is correct, battery voltage is adequate, sensors are being measured correctly, and the correct data are being collected.

c. Check that the sensors are working. Sensor calibration can change over time, and sensors can be disturbed or cables broken by animals.

d. Review the current readings (*6 mode). Review the stored data in *7 mode, or by down-loading it into a laptop computer or to a printer. This will help you find intermittent problems, and may save expensive return trips and further loss of data.

2.5 Archiving and Analysing the Data

Enter the data into a computer and review it as soon as possible. Plots of the data can be made to aid the review. The Campbell Scientific Inc. PC208 software and a spreadsheet program are easily used in the field with IBM compatible laptop computers. Fill out a form describing the data file, problems with the data and corrections required.

3 INSTALLATION OF DATA LOGGERS

3.1 Wiring and Testing the Measurement System

a. View the site and decide on sensor location. Determine the length of cable required for each sensor and then add 10%.

b. Soldering of wires and potting (sealing) joins and sensors should be done in the office. Minimize the need to join cables in the field. All joins should be soldered, and then covered of adhesive (inner-wall-melt) heat-shrink tubing or potting compound which must extend for 2 cm over uncut cable. Twisted wires and a terminal strip covered with electrical tape must not be used. Epoxies and electrical resins used in potting must be waterproof. Do not use 5-minute epoxy, as it absorbs water. Small butane-powered soldering irons and the adhesive heat-shrink tubing can be used in the field to join cables.

c. Tin (that is, cover with solder) the bare wire that is connected to the terminal strip on the logger. This bare section should not extend beyond the terminal strip, since this increases the risk of a short circuit. All wires must be shielded for as much of their length as is possible.

d. Connect all sensors to the data logger in the office to check that are working properly and the program is correct. Test for voltage offsets by monitoring a short circuit or a constant voltage supply. A known resistance can be used in place of a thermistor.

e. There never seem to be enough terminals on the data logger for all the shield and ground wires to be easily connected. Extra terminal strip can be used to aid connection.

f. In certain situations, it may be convenient to use an external connection box, rather than connecting the sensors directly to the data logger. Shielded cable should be used. Avoid using unshielded multiconductor ribbon cable. A separate, shielded cable should be used for an external battery.

g. Minimize the number of connections between a sensor and the data logger. Solder on the extension wire and insulate the join rather than using a terminal strip.

f. An unused input channel can be shorted at the data logger, or the connector box, and monitored with the lowest voltage range. This will provide a check of the data logger. A sensor problem on one channel can affect other channels.

3.2 Programming the Data Logger

a. Read the manual.

b. Write the program and test it before going to the field. The PC208 software contains a good programming aid.

c. Include the battery voltage, and identification number in the daily output. The panel temperature, year, and signature of the program can also be recorded with the 21X and CR10. The signature changes if the program is changed manually or if there is a failure in the data logger.

d. Determine the number of data points stored in memory in each output period, and the number of days of data the memory of the logger or storage module will hold. Note that:

- the maximum value of a variable with the time of occurrence counts as two data points.
- the output table number, Julian day, and time each counts as one data point - that is, three in this case.
- the output location numbers that identify each data point in printable ASCII format do not count.
- in the CR10 and the 21X, the number of values that will fill the memory is under half the size of the memory (e.g., a 48k memory will hold about 19.5k output values). The CR21 memory will hold 608 output values.

e. In the case of the CR10 and 21X, the output identification numbers run from 1 to 99. Thus, if there will be more than 99 values output in one time period, two or more output commands, each for less than 100 values, can be used in the same output table. The date and time should be in all output tables.

3.3 Power Supply

There are three choices of power supply: A.C. and rechargeable batteries, solar power and rechargeable batteries, and internal or external non-rechargeable batteries. Non-rechargeable batteries should always be of the alkaline type. Small rechargeable batteries should be avoided if the logger is not connected to a trickle charger (e.g., solar panel) or will not be visited often. These batteries do not last as long as similar sized alkaline batteries. Alkaline batteries maintain their charge in cold weather. Carbon batteries should not be used.

a. When external batteries are used on a 21X and there are also internal batteries, the power switch should be switched off after battery changes. This avoids the higher voltage battery trying to charge the lower one. Diodes can be used in the power line to stop this occurring.

b. Battery life should be estimated. If the logger is being powered by its internal alkaline batteries (8 D-cells), and is driving high current demand sensor or an AM32 multiplexer switching every 10-30 seconds, then the voltage can fall by 0.1 V/day. A voltage decrease of about 0.01 V/day can be expected with internal batteries and a low current demand (e.g., for thermistors, rain gauge and pyranometer with a 60-second scan rate). An external 12-V lantern battery will last for about 4 months when monitoring thermistors, quantum sensors, pyranometers, and thermocouples at a 10-second scan rate.

c. If the data logger is to be left for a long time without servicing, a large external battery supply (such as lantern batteries or a car battery) should be used. External batteries make servicing and battery changes easy. The internal ones can be use as a back-up while the external supply is being changed.

d. Battery voltage will decrease as the temperature decreases below 0°C. A large external battery should be used if the data logger is to experience extended periods below 0°C. Put the battery in the warmest possible location (e.g., below ground) and make sure it cannot be flooded.

e. Connect the positive wire first to the logger when you are connecting an external battery to reduce the chances of sparking. Do not short the battery leads while they are connected, as this will result in the failure of the data logger, and loss of the stored data the program. A pair of plugs that can only be connected one way can be used to make quick connections and to minimize the chance of shorting.

f. An external battery may cause a voltage offset on any single-ended voltage measurement (e.g. pyranometer) on early models of the 21X (1000 series serial number). An input channel can be shorted to monitor this offset and provide the correction required for voltage-output sensors.

3.4 Documentation and Checks

a. Document sensor location. Note the serial number of sensors being used and their location (e.g., height or depth, orientation, treatment, wiring code). All sensor wires should be labelled at the data logger. Labels can be attached under clear heat shrink tubing. Draw a map of the buried cables and sensors.

b. Once it is installed in the field, check that the data logger is measuring data correctly, using the *6 mode. Also check that it is storing data properly by setting the data logger for a short output time interval (e.g., 1 minute), and then reviewing the output in *7 mode. After verification, reset the logger to the correct output time interval.

c. Install back-up data collection facilities, that is, instruments not monitored by the data logger. A storage rain gauge and thermograph accompanied by maximum and minimum thermometers should be used.

d. Maintain a log of site visits, operations performed ,(e.g., program changes and data transfer), and weather conditions.

3.5 Protecting the Data Logger

The hazards to the data logger include temperature, moisture, lightning, animals, and vandals. All can usually be avoided by a careful choice of location and installation of the logger.

a. The logger can be located above or below ground. Campbell Scientific Inc. makes a robust, sealed container and mounting mast for the data loggers. Limitations to the mast are that it can be spotted by inquisitive people or used as a rubbing post for animals. During the winter the logger, and power supply may also be exposed to low temperatures. Partially burying the logger may avoid these problems, but there is a risk of flooding the logger if its container is not sealed or is located where water cannot drain away.

b. In a ground-level or below-ground level location, the logger should be in a small container inside a larger one. The Campbell Scientific Inc. container, plastic box, or a PVC pipe can be used as the smaller container. A plastic cooler (with a lip on the lid over-hanging the sides), a garbage can, a metal box, or a honey pail (with lid) partially buried in the soil make suitable outer containers. A wooden or fibreglass box should be used to cover the top of the outer container. This shades the container and reduces the temperature range to which the data logger is subjected.

Fibreglass insulation could be put inside the box if low snow pack conditions and air temperatures below -20°C may occur. If the data logger is to be serviced during the winter, a tall post or mast should be installed near the logger so that it can be easily located below the snow pack.

c. Avoid getting the data logger wet. If the container is partially buried, the inlet for the cables of the outer container must be 0.15 m above the soil surface, with the opening pointing down (e.g., with the use of a piece of angled pipe). The box over the container will help keep the pressure of snow or ice from cracking the lid of the container, and reduce the chance of melting snow and rain reaching it. Water must not be allowed to drain into any of the containers.

d. Packets of a drying agent should be placed inside the battery pack of the data logger (except in the CR10) and in the box containing the data logger. Use ONLY the packets of Humisorb supplied by Campbell Scientific Inc. and/or indicating silica gel (blue when dry, turning to pink when moist) in a permeable bag. Make certain that the drying agent cannot leak out of its bag. Dryrite is not recommended since it readily fractures, forming a dust.

e. Bare wires should not extend beyond the end of the terminal strip on the data logger. This minimizes the possibility of a short. Avoid the possibility of a short across the terminals of the external battery.

f. The 21X and CR10 have built-in lightning protection. However, as with the CR21, a good earth ground is required for the best protection. Connect a copper-coated grounding rod to the data logger with a braided copper grounding strip. The grounding rod should be buried to a depth of 0.5 m. See the data logger manual for further details.

g. Animals can use masts as rubbing posts, uproot guy-wires, and gnaw through cables and plywood shelters. Fencing can be used to keep some large animals away. Flag guy-wires so that they can be seen. Avoid using plywood in porcupine country. Cover a Stevenson's screen with a few layers of chicken wire. Exposed cables are likely to get chewed. Bury them, or run them through a conduit and bury the conduit if possible. Make sure there is no possibility of a tree falling on the data logger or masts.

h. There is always the potential for damage by vandals or even just curious passers-by. Where possible, choose a site well away from roads and trails. Reducing the size of above-ground material and burying the data logger reduces the

chance of the site being seen. A locked box embedded in concrete can also protect the logger. Label all equipment with clearly visible identification. A sign with a telephone number to call for more information may reduce the risk of accidental damage by the curious. If someone really wants to damage or steal the equipment, there is not much you can do, that is legal, to stop them.

4 OPERATION AND MAINTENANCE

4.1 Preparation for a Site Visit

a. Visit the data logger every 1 or 2 months during the summer. Site visits should be made every 1 to 2 weeks when manual measurements of soil moisture and temperature are to be made to complement data logger measurements.

b. Check that you have all the things you need to service the data logger, and have the correct time on your watch before leaving the office.

c. Maintain documentation on the installation and have a summary available at the site. This information should include the sensor locations and calibration, the input channel on the logger, a copy of the program, and a log sheet with data pointers, date of memory transfers, and battery and program changes.

d. Have some form of a shelter (e.g., a tarp.) available to cover the data logger and operator during servicing in the rain.

4.2 At the Site

a. Check that the data logger is reading all sensors correctly and is storing the information desired. Do not just collect the data and leave.

b. Check that the battery voltage is adequate to power the data logger until the next site visit (see Section 4.4).

c. Document visits on log sheets. Record the date and time of the site visit and the operations performed (e.g., battery change, data transfer), and note any sensor problems. Record the current readings of the sensors (*6 mode). Note whether the time indicates standard or daylight savings time. Record the name of the person servicing the logger.

d. Replace the external bag of drying agent on a monthly basis, if possible. The internal drying agent should be replaced each time the internal batteries are replaced, or every 6 months when an external battery is used.

e. Check that sensors are reading correctly. Air temperature and relative humidity sensors are checked with a psychrometer. The current temperature on a minimum thermometer can be used to check air temperature. Quantum sensor and pyranometer sensitivity should be checked annually, with sensors that are only used for this activity.

f. When taking down an installation, carefully remove all sensors and identify their location (treatment, depth, etc.) and channel on the data logger. Perform calibration checks in the field or on returning to the office

4.3 Retrieving and Reviewing Data

a. Retrieve data from the logger or storage module memory before doing any battery changes, program changes, removal of storage module, or sensor replacement.

b. Always review part of the data collected before leaving the site. The recorded data may show intermittent problems not apparent in *6 mode. The data can be reviewed in *7 mode, or with a laptop computer or battery-driven printer. When reviewing data, question whether the values seem reasonable. You will need to determine what are reasonable values. If necessary, use manual probes to check the monitored sensors.

4.4 Battery Maintenance

a. Change the batteries if the battery voltage is less than 10 V. If the voltage is greater than 10 V, determine if it is likely to drop below this value before the next visit. If the logger is being powered by internal alkaline batteries (8 D-cells), and is driving high current demand sensors or an AM32 multiplexer switching every 10-30 seconds, then the voltage can fall by 0.1 V/day. A voltage decrease of about 0.01 V/day can be expected from internal batteries with a low current demand (e.g., thermistors, rain gauge and pyranometer with a 60 second scan rate). Large, external batteries last longer than the internal batteries. An external 12-V lantern battery will last for about 4 months when monitoring thermistors, pyranometers, and thermocouples at a 10-second scan rate. The battery voltage will decrease if the temperature falls below 0°C. When in doubt, change the batteries; they are inexpensive compared to the cost of obtaining the data.

b. The power switch should be off when an external battery is being used and there are internal batteries. This avoids the fresh battery charging the old batteries. The switch can be on for the duration of the battery change.

c. Check the polarity of the battery cables before connecting them. Check that new batteries are properly connected before disconnecting the old ones, by monitoring the battery voltage during the change. The voltage should increase substantially when the new batteries are connected.

d. The battery measurement instruction and IF statements can be used in the 21X and CR10 to disable most of the program when the battery voltage falls below a certain level. This will reduce power consumption and the chance of losing the data already collected.

4.5 Reprogramming the Data Logger.

a. The data logger can be reprogrammed while in operation, but data will be lost. The monitoring section of the program is interrupted and reset (that is, the next output summary will be a summary from the time of reprogramming to the time of output). Thus, a program change at 1420 means that the 2400 summary will only be for the period 1420 to 2400. There is no easy way to recover any data relating to the period 0000 to 1420 that has not been placed in output storage (e.g., through a previously programmed hourly output command). The CR10 and 21X have programmable toggle switches that can be used to manually enable or disable parts of the program (in *6 mode) without data loss. Double check the logic of the program when using this approach. Disabling a section could mean turning off the CR10 tape enable instruction. Enabling could result in overwriting an input storage location.

b. Enabling or disabling tape and printer output (21X and CR10 *4 mode), or changing time and date (*5 mode) is equivalent to reprograming the data logger.

c. Reprogramming the 21X and CR10 will reset the start-of-data pointer to the current end-of-data pointer. This is why data should be retrieved before the logger is reprogrammed. This error is recoverable. Reset the start-of-data pointer (see Section 5) and record the data.

d. Increasing the size of the data logger program in the 21X and CR10 may result in an overflow of the input or intermediate storage space allocation. An E04 or E11 error message after you have returned to *0 mode indicates that this has happened. More memory can be allocated through the *A mode. However, **MEMORY RE-ALLOCATION WILL ERASE ALL THE STORED DATA.** Retrieve all the data in the memory before re-allocation.

4.6 Leaving the Site

Double check that the data logger is in *0 mode before replacing it in its container. The display of the CR21 indicates 99 and the time, and the 21X and CR10 indicate LOGxx. Power consumption is increased if the logger is not left in *0 mode.

5 RETRIEVAL OF DATA

5.1 Battery Voltage Check

The battery voltage should be greater than 9.5 V when recording data on tape recorders powered by the logger. If the voltage is low, connect a new external battery, but do not disconnect the old one. Proceed carefully. All stored data and the program will be lost if power is lost during a battery change. Check that the battery voltage is adequate before continuing.

5.2 Checking the Data Pointers

a. Record the data pointers on the log sheet. Check that the previous end-of-data pointer corresponds with the present start-of-data pointer (21X and CR10). Only the end-of-data pointer is shown in the case of the CR21. The end-of-data pointer at the previous data transfer should have been recorded at that time. Leave a copy of this information with the logger.

b. Full memory retrieval must be done if there has been a memory overflow. A hint that this may have occurred is that the present and previous end-of-data pointers appear too close - that is, only a small amount of data appears to have been stored since the last interrogation. To determine if this has happened, check the stored data using the *7 mode. For the 21X and CR10, reset the start-of-data pointer to one greater than the current end-of-data pointer and proceed as normal. To retrieve the complete memory with the CR21, set the end-of-data pointer to 1 greater than the current end-of-data pointer and proceed as normal. This highlights the need for determining the data storage rate before begining the measurement programme.

5.3 Retrieval on Tape

a. Tape recorders do not always function correctly below about 5°C. When interrogating a logger in cooler than 5°C temperatures, keep the tape recorder warm when not in use by placing it inside your jacket.

b. Use normal bias 30- or 60-minute tapes, as they are less likely to stretch than the 90-minute tapes. Have a 10-second blank on the tape separating different tape transfers. Make sure you are past the last record on the tape before re-using it. Erase tapes before recording over old data.

c. Before connecting the tape recorder to the data logger, place a vocal record of location, date, time, data logger identification, and name of the operator on the tape.

d. Connect the recorder to the logger. Check that the plugs are in the correct sockets and the record button is down. Place a piece of tape over the unused monitor socket. Reset the data pointers, if necessary, and then record the data.

e. Check the quality of the recording when finished. Remove the recorder and rewind the tape a short distance and listen to it. Re-record the data if the recording is of poor quality. To do so, reset the start-of-data pointer to its original value since it will now equal the end-of-data pointer. The original number should have been noted on the log sheet.

f. When the tape record is acceptable, place a 10-second blank trailer at the end of the tape and reset the data logger to *0 mode.

g. When a tape recorder is left in the field for continuous recording, a test recording (using *8 mode) should first be made. Check that the plugs are in the correct sockets, the record button is down, the pause button is off, and output mode for the CR10 and 21X is enabled.

h. A cable (SC12) with three ends is required to connect a computer or CR10KD keypad, and the logger/cassette interface to the CR10. Ignore the characters appearing on the computer screen during the data transfer to tape.

5.4 Retrieval with a Portable Computer

Data can be stored in the computer or, in the case of the CR10, a computer can be used to initiate a transfer to tape. In the latter case, where the computer is being used as a key pad, also see Section 5.3.

a. Determine the communications protocol - that is, baud rate, parity, word length, and stop bits. The computer should be set for capital letters. The 21X and CR10 allow several baud rates, have an 8-bit word length, and no parity. The CR21 uses 300 baud, 7-bits, 1 stop bit, and even parity. Garbage on the screen (except during recording on tape) indicates that the protocol is incorrect.

   Test the data transfer under different baud rates. Because the logger does not recognise the interrupt signal from the computer that indicates that its memory buffer is full, data can be lost if the transfer rate is too high. The Radio Shack 100/102 should be used at 300 baud (though a faster

rate can be used when communicating with other computers). The newer laptops can work at 1200 baud. Communication can be at higher rates if there is no data transfer.

b. Connecting the logger to the computer. Laptop computers and the PC 201 card do not need the optically isolated interface. In fact, this interface can cause some laptops to crash. The interface is need with a standard serial port on a PC. There are various forms of communication software available to retrieve the data. Any IBM compatible can be used with the PC208 software from Campbell Scientific Inc. The Radio Shack 100/102 has telecommunications capabilities built in (set XON/XOFF = D and set to full duplex mode to disable repetition of key strokes). The Husky requires user-written software. A copy can be obtained from the author.

c. After communication has been initiated, the logger will sign off after 40 seconds if it receives no signal from the computer. Make sure you are ready to go once communication is initiated.

d. After recording the data, review the file. Strings such as XXXXX indicates that these data could not be read. Check the interface cable and re-record the data. A string such as XX in the output identification number indicates that the first part of the output summary was missing. This probably resulted from a memory overflow and should only be on the first output summary. These identification numbers cannot be recovered; however, the data are good and represent the last part of the output record.

e. Note the file name, date and time on the log sheet.

f. Make a tape record as a back-up in case the floppy disks are lost or damaged. The start-of-date pointer must be reset to its original value to re-record the data.

g. Reset the data logger to *0 mode.

5.5 Retrieval from a Storage Module

Storage modules can be replaced and returned to the office for transfer to a computer, or the data transfered to a cassette tape and the module left with the logger.

a. The internal lithium battery in the module should be checked before installation of the module. The data will be lost if the module cannot maintain power when disconnected from the data logger. Make a tape record as a back-up if the module is to be removed.

6 PRELIMINARY ASSESSMENT OF THE DATA

6.1 Cassette Tape Storage

a. Enter the cassette-tape record into a computer as soon as possible. Check the quality of the cassette record before input. The playback heads may need to be re-aligned if a tape recorder other than that used to record the data is used for playback.

b. A string such as XXXXX indicates that the data could not be read. This could result from the tape recorder playback heads being incorrectly aligned, or the volume being too low or too high. After correcting these problems, re-enter the data. Transferring the data with different volume and head alignment may give the previously misread data, while also giving errors on previously correctly read data. A complete file can be made by the patching together of the correct records with a word processor such as PCWRITE (ASCII files are standard). If the data cannot be recovered, you will have to return to the data logger to re-record the data.

c. A string such as XX as the output identification number (printable ASCII format) indicates that the first part of the output summary was missing. This probably resulted from a memory overflow and should only be on the first output summary. These identification numbers cannot be recovered; however, the data are good and represent the latter part of the output record. A string such as XX can also result from the CR20 interface being reset.

6.2 Laptop Computer Storage

A number of computer communications packages are available for serial ports. The Campbell Scientific Inc. PC208 software works with IBM compatibles, and in the PC communicating with a Radio Shack 100/102. The latter requires the enabling of line feed with carriage return. Enter BASIC and issue the command POKE 63066,255. Software for the Husky is available from the author.

6.3 Processing the Data

a. Process the data as soon as possible into a form that can be reviewed. The PC208 software can be used on IBM compatible laptops in the field. Review the data (e.g., as graphs in a spreadsheet).

b. Maintain a record of the computer file names, data source, and possible problems with the data.

c. The first few lines of the archived files should contain site name, location, editing information, and column labels. Make a back-up copy of the data files.

d. Save the cassette tapes. Tapes should not be erased until you are certain that the data in the computer are correct and fully backed up. Preferably wait until the project is finished before erasing the tapes. Cassette tapes are inexpensive, data are not. The remaining portion of the tape can be used for further recordings; but care must be taken not to overwrite existing data records.

7. ERROR CHECKING

7.1 Error Messages from the 21X and CR10

Most of the frequently observed error messages indicate only minor problems (e.g., E04). Usually they can be solved by allocation of more space to certain operations, or reduction of the length of the program. See the manual for the procedure. **RE-ALLOCATION OF MEMORY WILL RESULT IN THE LOSS OF ALL DATA IN INTERMEDIATE AND OUTPUT STORAGE.**

The message E08 indicates a major problem. Usually, the data logger will not respond and may have to be switched off (with the subsequent loss of data) to recover from this error. Try adding a new battery if the voltage is very low.

7.2 Data Logger Not Responding to Keyboard Commands

a. Data logger keyboard control: Freezing of the display (no response to the keys) may be a result of condensation on the circuit boards. Keyboard control may be regained after drying out the logger. However, switching the data logger off after drying it may be the only recourse to recovery. In this situation, the data will be lost.

b. CR10KD keyboard and display control: The keyboard is not sealed. Moisture in the keyboard can cause freezing of the display. Disconnect the keyboard, dry it, and reconnect. Make certain the keyboard is functioning before assuming that there is a problem with the CR10.

c. Computer control: Check that the communications protocol is correct. Try disconnecting the computer and then re-initiating communication. Check that your computer is not suffering from a problem caused by internal condensation.

d. If using an external battery, verify that the power supply is adequate and connected. Check that the cables connecting the devices are secure.

7.3 Display Off

a. Check if the power switch is in the correct position, and any external batteries are connected correctly.

b. Using a multimeter, check that the battery voltage is greater than 8.5 V. If the batteries are dead, then data that were stored in the data logger memory are lost.

7.4 Reviewing Data in *6 Mode

Erroneous readings can be obtained in many ways. First check that the logger is programmed correctly and then check for problems with the wiring and the sensors.

a. Reading 0 or strange numbers on most channels could mean a low battery voltage, condensation, or problems with the sensors. Connect a new battery if the voltage on the old ones is low. The data stored in memory should not have been lost. If there is no response to a new battery supply, you may have a condensation problem inside the data logger. The data in memory may still be retrievable. The *8 mode may work, but leave the fresh battery connected. Return the data logger to the office to dry it out. Disconnect the sensors one by one and check them with a multimeter. Note if the removal of a sensor affects the reading from other sensors.

b. A sensor output of 6999, -6999, or 9999 indicates that the measurement circuit is over-ranging. This can be caused by a program error, such as measuring on too low a voltage range or with the wrong program. Over-ranging can also indicate an open circuit. A disconnected ground wire (AG on the CR10) will cause this problem to occur on a thermistor. Check for chewed or broken cables.

c. A moisture block reading of -1.0 on a CR10 or 21X indicates that the return wire (ground) is disconnected.

d. A thermistor temperature that appears too low is usually the result of a spurious resistance developing in the circuit. This resistance may be temperature-dependent, resulting in fluctuations from too low to reasonable values during the day. Conversely, thermistors can also read too high due to partial shorting or degredation. This problem is most likely to occur with soil temperature sensors.

e. A reading of around -50.0 on a thermistor means that there is negligible voltage across the measurement resistor. This indicates that either the excitation line is disconnected, or there is a short across the measurement resistor.

f. A reading of about 85 with a thermistor on a CR21 indicates that the low side (ground) may be disconnected.

g. A voltage sensor (e.g., a pyranometer) reading close to zero when it should be higher indicates a short circuit or open circuit in the sensor or cables. If possible, connect a replacement sensor to make sure the problem is with the sensor and not the logger. Note that pyranometers and quantum sensors can give negative values at night. Reject these data.

h. Erroneous readings may be obtained with a 21X if a sensor is not isolated from the ground. This will occur where one of the leads is connected to the body of the sensor and the body is connected to the soil. For example, to correct this problem with a Stewart anemometer on a metal pole; insert a plastic coupling between the anemometer and the pole to act as an insulator.

7.5 Zero Offset

a. The use of unshielded cable can result in voltage offsets.

b. There may be a small negative voltage offset of 0.05-0.3 mV on a single-ended voltage measurement when an external battery is used on a 21X (1000 series serial number). To monitor the offset, use a shorted channel.

c. Disconnect sensors one by one to see if the offset disappears.

7.6 Memory Overflow

It is advisable to know how much the memory will be filled between site visits. Memory overflow is indicated when the difference between the start-of-data pointer and current end-of-data pointer (CR10 and 21X), or the present and previous end-of-data pointers (CR21), appears to be too low. Since the memory is circular, the start pointer can be at a higher number than the end pointer without a problem having occurred. Manually check the memory using the *7 mode. If the problem is a memory overflow, reset the start-of-data pointer to one more than the end-of-data pointer and record the data. The data that have been overwritten are lost. An incorrect amount of data in memory can also result from a programming error.

7.7 Cassette Tape Record

a. If there are no data on the tape, check that the plugs are in the correct sockets, the record button is down and the pause button is off. Reset the start-of-data pointer and record the data.

b. Noisy data (static) recorded on the tape suggests a problem with the cassette recorder interface cable.

c. A weak recording may be due to a cold (<5°C) tape recorder battery (CR21) or a bad tape. Check the plugs and try warming the tape recorder with body heat before resetting the data pointer and re-recording the data.

d. No data on the tape in a cassette recorder left in the field to record data continuously could be the result of a number of problems:

- the tape had been advanced. The plug was probably not in the record input, or the record button was not depressed.
- the tape had not moved - CR21. The tape recorder was not switched on, the pause switch was on, or the tape recorder batteries were dead. The CR21 does not provide power for the tape recorder.
- the tape had not moved - 21X and CR10. The logger was not programmed for continuous output, the tape recorder was not switched on, or the pause switch was on.
- the tape recorder was off. It may have been accidentally left off. However, a tape that sticks will act like a finished tape and cause the recorder to switch itself off.

Make a recording of the whole memory to recover as much of the data as possible (see Section 5).

7.8 Storage Module

a. If there is no data in the module, check that output has been initiated. Check that the baud rate is set correctly.

b. The internal lithium battery in the module should be checked before installation. The data will be lost if the module cannot maintain power when disconnected from the data logger.

7.9 Computer Control

a. If garbage appears on the screen, the communications protocol is probably incorrect. Note that garbage on the screen during a data transfer to tape is normal.

b. Commands being repeated mean that half rather than full duplex mode has been set.

c. Check that the cables connecting the devices are secure.

d. If using an external battery, verify that the power supply is adequate and connected.

8 OPERATIONS SPECIFIC TO EACH DATA LOGGER MODEL

8.1 The CR21

a. Early versions of the CR21 have the output rate calculated as a multiple of 10 seconds. The others use multiples of one minute.

b. In early versions of the CR21, if the output rate is set at 24 hours the logger will not start logging until midnight. Later versions start logging as soon as the program table is activated, and will give an output at midnight for the period since activation. This means that you do not have to wait 2 days to make sure everything is working.

Items a and b can be resolved by the installation of new PROMS.

c. Telecommunications protocol for the CR21 is even parity with 7-bit words and 1 stop bit. Baud rate is fixed at 300 baud.

d. Some CR21's have a 10-second scan rate. (This is different from the problem discussed above in [b].) It is not a problem, but you should be aware of it when using a pulse counting channel with an anemometer.

e. The CR21 can only store 608 data points in memory. It is easy to overflow this size of memory.

f. Only output table 1 has the date and time in the output. This cannot be changed and date and time cannot be output in tables 2 and 3.

g. The display (*6 mode) is updated continuously. Battery voltage is in channel 0 and scanning does not need to be initiated with a program command.

h. Cassette tape interfaces for the CR21 will not work with the other models. Also, an unmodified SC235 cannot be used with a CR21 converted to FORMAT II.

i. New storage modules will not work with old PROMS.

j. The A-235 will not read FORMAT II tapes.

8.2 The 21X

a. Unlike the CR21, the 2400-hour output is coded as 0000 and the day number is advanced by one over the value that you would get for a 2359-hour output. This can be annoying, since the data summary represents the day previous to that indicated

by the day number. The Campbell Scientific Inc. PC208 software can be used to correct this during data processing on your computer.

b. Unlike in the CR21, the 21X requires a battery-read instruction to be included in the program for measuring battery voltage. It should be executed at the same rate as the other sensors.

c. Continuous tape or printer output must be enabled in *4 mode.

d. The display (*6 mode) in the 21X is updated at the execution rate.

e. Erroneous readings may be obtained with a 21X if a sensor is not isolated from the ground. For example, when the metal body of an anemometer is in the circuit and the anemometer is installed on a metal pole.

8.3 The CR10

a. The CR10 is similar to the 21X, but the output problem described in 8.2 (a) can be avoided through programming. Continuous tape output is enabled through instruction P96.

b. Communicating with standard serial ports of PC's requires the SC32 optically isolated interface. The PC201 card, laptops such as the Toshiba, and the Radio Shack 100/102 do not need the SC32.

c. The screen on a PC does not automatically update at the scanning rate when interrogating the CR10 in *6 mode. The PC208 software can be used for automatic updates (an IBM compatible PC is required). The CR10KD keyboard also updates automatically. If neither of these options is available, the A (advance) or ENTER, and B (backup) keys must be used.

d. On the wiring panel, AG (analogue ground) is for the return (low) lead of a sensor; G (ground) is for the battery negative terminal and for sensor shield wire.

e. The SC92A cassette write interface should be used for transferring data to tapes. Versions for the CR21 (SC235) and old SC92s will not work.

f. Do not fasten the right-hand screw of the SC92A to the connector on the wiring panel. This will cause a short to the metal case of the CR10. Using the plastic SC12 between the logger and the interface avoids this problem.

9 INSTRUMENTATION

Data loggers can collect a lot of data with high resolution. However, the accuracy of these data may be much less than the resolution with which they were measured. This section briefly reviews sources of error in a monitoring programme, assesses sensors typically used in such a programme, and recommends reporting increments for the measurements.

9.1 Accuracy of Measurements

This discussion is based on material in Gill and Hexter (1972) and Fritschen and Gay (1979). The 21X and CR10 manuals have information on error of the data loggers and various sensors. Measurements can be described in terms of error, resolution, repeatability, and accuracy. These four conditions affect the reporting increment, or significant digits, for the measurement. Some authors have equated the term precision with reporting increment and others with repeatability. I favour the latter definition, but will not use the word in this discussion.

Error of an instrument is the difference between the indicated value and the true value of the signal. It is composed of systematic and random components. A systematic error (or bias) does not change between repeated measurements. It is equal to the difference between the true value and the mean of a large number of measurements. An example would be a constant voltage offset. Random errors vary between measurements. They result from electrical noise, fluctuations in temperature, and operator error.

Resolution of an instrument is the smallest change in the environment that causes a detectable change in the instrument. For example, if the data logger has a resolution of 1 microvolt (μV), the resolution for a thermocouple with a sensitivity of 40 μV/°C is 1/40 = 0.025°C.

Repeatability is the closeness of agreement among a number of consecutive measurements for the same value of the input under the same operating conditions. High repeatability does not necessarily imply high accuracy.

Accuracy of an instrument is the degree to which it will measure a variable in terms of an accepted standard or true value. (The term accuracy is usually measured in terms of inaccuracy but expressed as accuracy.) In the above example, the logger may resolve 1 μV, but through the stability of its reference voltage be accurate to only ±2 μV. Thus, the thermocouple measurement is only good to ±0.05°C. The accuracy of the thermocouple calibration is considered below.

Reporting increment or significant figures is the smallest unit of measurement that should be used in reporting the data. It is a summation of the accuracy of all parts of the sampling and measurement process.

Sensitivity is the change in output of the sensor in response to a change in the variable being measured.

Many factors can result in measurement error and must be considered in determining the reporting increment. These are:

Data logger measurement circuitry, e.g., quality of components, stability of reference voltage.

Programming of the data logger, e.g, using the correct program and measurement range.

Sampling interval, e.g., averaging over an hour to obtain a temperature, rather than spot-reading at the end of the hour.

Sensor and cables, e.g., accuracy of calibration and maintenance of this calibration, condition and quality of the wiring between the sensor and the logger.

Exposure of sensor, e.g., avoiding shade of a pyranometer, placing the sensor at the appropriate location.

Replication, e.g., accounting for variation within the monitored area.

Some of the above sources of error are larger than others and their importance will depend on the measurement. For example, sensor accuracy is usually less than that of the data logger. Less replication is required to obtain an accurate measure of air temperature at 2 m than at the soil surface.

The thermocouple noted above can be used as a hypothetical example to illustrate the various errors. The analysis is somewhat simplified. The error is dependent on the electronic, mechanical and mathematical transformations in the measurement system. Differences, ratios and non-linear transformations are treated differently. Fritschen and Gay (1979) and other citations in the Bibliography should be referred to for more detail.

A measurement accuracy of ±2 μV (±2.5 mV range) will be assumed for the logger, equivalent to ±0.05°C for the thermocouple. If the ±2.5 V range had been programmed, then accuracy would have been ±2 mV and ±50°C for the data logger and thermocouple, respectively. The thermocouple sensitivity has an

uncertainty of ±5% (i.e. an accuracy of ±0.05°C), and it is connected to a reference temperature that is also accurate to ±0.05°C. Consequently, the reading on the panel of the data logger or on the computer screen has an absolute error that is the sum of the three errors; 0.05 + 0.05 + 0.05 = ±0.15°C. (In this case a linear model can be assumed.) This is a worst case situation. The probable error assumes that errors in the different parts of the measurement system will tend to compensate for each other. It is approximately two-thirds the size of the absolute error.

We will continue to be conservative and use the absolute error of ±0.15°C. Thus, the reporting increment for the thermocouple based on instrument errors is 10ths of a degree, and temperature should be rounded to the nearest 0.2°C. Non-instrument errors are more difficult to determine. Past experience is the best guide, such as knowing the variability in space and in time. For example, a shorter scanning interval is required to obtain a reliable half-hourly average of surface temperature as opposed to that required for the 10 cm soil temperature - 1 second and 1 minute, respectively. Similarly, we need more spatial replicates of the surface temperature.

9.2 Examples of Sensor Accuracy and Reporting Increment

Table 1 presents data on sensors typically used in climate stations and biological studies (that is, the low to medium price range). Sensor accuracy will vary with age and amount of use the sensor has had since the last time it was serviced and calibrated. Accuracy is often expressed as a percent of the reading rather than as an absolute value, and this may vary with the measurement range. The accuracies quoted in the table assume that the measurement system is well maintained and sensors correctly calibrated. If this is not the case, accuracy can degrade by a factor of two or more.

The soil temperature and moisture sensors require replication to obtain an accuracy for the site average similar to that of the measurement of an individual sensor on the data logger. This will vary with the depth and the variability of the site being monitored. Past experience, pilot studies, and a knowledge of the end use of the data are required to determine the degree of replication required for an acceptable level of accuracy.

Table 1. Accuracy and reporting increment (significant figures) of typical environmental sensors monitored with the Campbell Scientific Inc. data loggers. **Values are for well maintained sensors and adequate power for the data logger.**

Variable		Significant figures	Units	Accuracy (±)	Comments
Solar radiation	hourly	xx0	W m^{-2}	larger of 5% and 10	sensitivity declines by about 1% or more per year for silicon cell based sensing elements
	daily	xx.x	MJ m^{-2} d^{-1}	larger of 5% and 0.5	
Photosynthetically active radiation	hourly	xxx0	µmol m^{-2} s^{-1}	larger of 5% and 20	
	daily	xx	mol m^{-2} d^{-1}	larger of 5% and 1	
Air temperature		xx.x	°C	0.2	stable
Relative humidity		xx	%	3	capacitance elements can degrade, poor above 90%. check calibration often
Vapour pressure		x.xx	kPa	0.05	
Wind speed	≤ 1.5 m s^{-1}	xx.x	m s^{-1}	0.5	stall speed increases with age
	≥ 2 m s^{-1}	xx.x	m s^{-1}	0.2	
Wind direction		xx0	°	15	
Rainfall	1-mm bucket	xx	mm	1	pollen and insects will block funnel
	0.3-mm bucket	xx.x	mm	0.3	
Soil temperature		xx.x	°C	0.2	ensure well sealed
Soil moisture block	≥-0.2 MPa	x.xx	MPa	0.05	contact poor in coarse soil, dissolve in acidic soil
	≤-0.3 MPa	x.x	MPa	0.2	

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APPENDIX I Input program form for the CR21

CR21 Input Table Coding Form

CR21 ID _____ Start Date _____ Start Time _____

NOTE: Select input program numbers from appendix A of the CR21 Operator's Manual. Specify a multiplier (a) and offset (b) for each sensor using the equation EU = aX + b to convert the sensor output (X) to engineering units. EU = Final Output Engineering Units. IU = Input Units e.g. volts (V), millivolts (MV), and counts.

Sensor Number	Sensor Description and Calibration				Final Output (EU)
	Range (EU)	Input Program	Program No.	Multiplier (EU/IU)	Offset (EU)
	(V, MV, DC Resistance)				
1			11:	12:	13:
	(V, MV, DC Resistance)				
2			21:	22:	23:
	(V, MV, DC Resistance)				
3			31:	32:	33:
	(V, MV, DC Resistance)				
4			41:	42:	43:
	(V, MV, DC & AC Resistance)				
5			51:	52:	53:
	(V, MV, DC & AC Resistance)				
6			61:	62:	63:
	(V, MV, DC & AC Resistance)				
7			71:	72:	73:
	Pulse counter (4095 counts per scan maximum)				
8			81:	82:	83:
	Pulse counter (15 counts per scan maximum)				
9			91:	92:	93:

CR21 Input Table Coding Form

CR21 ID 3076 Start Date 28 May, 1984 Start Time 09:30 PST

NOTE: Select input program numbers from appendix A of the CR21 Operator's Manual. Specify a multiplier (a) and offset (b) for each sensor using the equation EU = aX + b to convert the sensor output (X) to engineering units. EU = Final Output Engineering Units. IU = Input Units e.g. volts (V), millivolts (MV), and counts.

Met site E.P. 966 10 sec. scan

Sensor Number	Sensor Description and Calibration				Final Output (EU)
	Range (EU)	Input Program	Program No.	Multiplier (EU/IU)	Offset (EU)
	(V, MV, DC Resistance)				
1	Pyranometer				$MJ\ m^{-2}\ d^{-1}$
	mV		11: 2	12: 13.27	13: 0
	(V, MV, DC Resistance)				
2	Air temp - screen - thermistor				
	D.C. Res.		21: 7	22: 1.0	23: 0
	(V, MV, DC Resistance)				
3	R.H. screen Micromet.				
	V		31: 1	32: 41.2	33: 5.0
	(V, MV, DC Resistance)				
4	Soil temp. - 10 cm Control				°C
	D.C. Res.		41: 7	42: 1.0	43: 0
	(V, MV, DC & AC Resistance)				
5	Soil temp. -20 cm Control				°C
	D.C. Res.		51: 7	52: 1.0	53: 0
	(V, MV, DC & AC Resistance)				
6	Soil temp. - 10 cm Mound				°C
	D.C. Res.		61: 7	62: 1.0	63: 0
	(V, MV, DC & AC Resistance)				
7	Soil temp. -20 cm Mound				°C
	D.C. Res.		71: 7	72: 1.0	73: 0
	Pulse counter (4095 counts per scan maximum)				
8	Windspeed				$m\ s^{-1}$
			81: 6	82: 0.08	83: 0.45
	Pulse counter (15 counts per scan maximum)				
9	Rainfall				mm
			91: 6	92: 1	93: 0

APPENDIX II Output program form for the CR21

CR21 Output Table Coding Form

CR21 ID _____ Start Date _____ Start Time

NOTE: Select output program number and parameters from appendix B of the CR21 Operator's Manual. Output ID numbers 1, 2 and 3 identify table number, day and time. ID numbers 4 and greater identify data generated by ouput programs. Only positive integers are used to program the output table.

Output Table Number (1, 2 or 3) _____ Output Time Interval (minutes) 03: _____

Table Entry Number	Output Program and Data Description				Output ID No.
	Param 1 descrip.	Param 2 descrip.	Program No.	Parameter 1	Parameter 2
1			11:	12:	13: 4
2			21:	22:	23:
3			31:	32:	33:
4			41:	42:	43:
5			51:	52:	53:
6			61:	62:	63:
7			71:	72:	73:
8			81:	82:	83:
9			91:	92:	93:

CR21 Output Table Coding Form

CR21 ID 3076 Start Date 28 May 1984 Start Time 09:30 PST

NOTE: Select output program number and parameters from appendix B of the CR21 Operator's Manual. Output ID numbers 1, 2 and 3 identify table number, day and time. ID numbers 4 and greater identify data generated by ouput programs. Only positive integers are used to program the output table.

Output Table Number (1, 2 or 3) 1 Output Time Interval (minutes) 03: 1440

Met. Site E.P.966

Table Entry Number	Output Program and Data Description					Output ID No.
	Param 1 descrip.	Param 2 descrip.	Program No.	Parameter 1	Parameter 2	
1	Pyranometer		MJ m^{-2} d^{-1}			4
	Average		11: 51	12: 1	13: 0	
2	Air temp. screen		°C			5
	Average		21: 51	22: 2	23: 0	
3	Air temp. screen					6,7
	Maximum	Time	31: 53	32: 2	33: 1	
4	Air temp. screen		°C			8,9
	Minimum	Time	41: 54	42: 2	43: 1	
5	R.H		%			10, 11
	Maximum	Time	51: 53	52: 3	53: 1	
6	R. H.		%			12, 13
	Minimum	Time	61: 54	62: 3	63: 1	
7	Windspeed		m s^{-1}			14
	Average		71: 51	72: 8	73: 0	
8	Wind speed		m s^{-1}			15, 16
	Maximum		81: 53	82: 8	83: 1	
9	Rainfall		mm			17
	Total		91: 52	92: 9	93: 0	

APPENDIX III Input program forms for the 21X and CR10

21X AND CR10 SENSOR INPUT FORM Page __ of __

LOCATION: _____ DATA LOGGER: _____

FROM: DATE _____ JD _____ TIME _____

TO: DATE _____ JD _____ TIME _____

SENSOR DESCRIPTION	UNITS	INPUT CHAN.	INT.ST. (*6)

21X AND CR10 PROGRAM FORM Page __ of __

LOCATION:_____ DATA LOGGER:_____ TABLE:___

DATE:_____ OUTPUT INT.:_____ min EXEC. INT.:_____ sec

INSTR. LOC.	PARAM. NO.	ENTRY	DESCRIPTION

21X AND CR10 SENSOR INPUT FORM Page 1 of 2

LOCATION: EM Fire, Williams Lake DATA LOGGER: 21X-1221
FROM: DATE 14 March, '87 JD 104 TIME 16:00 PST
TO: DATE _____ JD _____ TIME _____

SENSOR DESCRIPTION	UNITS	INPUT CHAN.	INT.ST. (*6)
Pyranometer	$W m^{-2}$	1	1
Air temp. screen } 207 probe	°C	2	2
R.H. screen } 207 probe	%	3	3
Soil temp. 1 0.5 cm } Grass	°C	4	4
2 5.0 cm } Grass	°C	5	5
3 15.0 cm } Grass	°C	6	6
4 0.5 cm } Trees	°C	7	7
5 5.0 cm } Trees	°C	8	8
6 15.0 cm } Trees	°C	9	9
Air temp. 20 cm	°C	10	10
Moisture block 1 5.0 cm } Grass	kΩ	11	11
2 15.0 cm } Grass	kΩ	12	12
3 30.0 cm } Grass	kΩ	13	13
4 5.0 cm } Trees	kΩ	14	14
5 15.0 cm } Trees	kΩ	15	15
6 30.0 cm } Trees	kΩ	16	16
Wind speed	$m s^{-1}$	1p	17
Rainfall	mm	2p	18
Battery voltage	V	-	19
Vapour pressure deficit	kPa	-	20
Pyranometer	$MJ m^{-2} d^{-1}$	1	21
Identification	-	-	22

21X AND CR10 PROGRAM FORM Page 1 of 5

LOCATION: E.M. Fire, Williams Lake DATA LOGGER: 21x-1221 TABLE: 1

DATE: 14 March, 1987 OUTPUT INT.: 1440 min EXEC. INT.: 10 sec

INSTR. LOC.	PARAM. NO.	ENTRY	DESCRIPTION
1	P	1	Voltage Pyranometer
	1	1	Reps.
	2	2	± 15 mV range
	3	1	Input chan.
	4	1	storage loc.
	5	100	$W m^{-2} mv^{-1}$
	6	0	
2	P	11	Temp. -107 probe Air temp. screen
	1	1	Reps.
	2	2	Input loc.
	3	1	Excitation chan.
	4	2	Storage loc.
	5	1	°C
	6	0	
3	P	12	207 probe R.H. screen
	1	1	Reps.
	2	3	Input loc.
	3	1	Excitation chan.
	4	2	Ref. temp. loc.
	5	3	Storage loc.
	6	1	o/o
	7	0	

APPENDIX IV Output table form for the 21X and CR10

21X and CR10 OUTPUT TABLE FORMAT Page __ of __

LOCATION:_____ DATE:_____

TABLE:_____ FILENAME:_____

ID	Variable	Unit	Type	ID	Variable	Unit	Type
1				24			
2				25			
3				26			
4				27			
5				28			
6				29			
7				30			
8				31			
9				32			
10				33			
11				34			
12				35			
13				36			
14				37			
15				38			
16				39			
17				40			
18				41			
19				42			
20				43			
21				44			
22				45			
23				46			

COMMENTS:

21X and CR10 OUTPUT TABLE FORMAT Page 1 of 2

LOCATION: EM Fire, Williams Lake DATE: 14 March, 1987

TABLE: 116 - Daily data FILENAME: WL87X104 . DAT

ID	Variable	Unit	Type	ID	Variable	Unit	Type
1	Table i.d.			24	Air temp.-screen	°C	Min
2	Julian day			25	"	PST	Time
3	Time	PST		26	R.H. screen	%	Min
4	Solar radiation	$MJm^{-2}d^{-1}$	Total	27	"	PST	Time
5	Air temp.-screen	°C	Avg	28	Soil temp. 0.5cm)	°C	Min
6	Soil temp. 0.5cm)	°C	Avg	29	5.0 cm (grass	°C	Min
7	5.0cm (grass	°C	Avg	30	15.0 cm)	°C	Min
8	15.0cm)	°C	Avg	31	0.5cm)	°C	Min
9	0.5 cm)	°C	Avg	32	5.0 cm (trees	°C	Min
10	5.0 cm (trees	°C	Avg	33	15.0 cm)	°C	Min
11	15.0 cm)	°C	Avg	34	Air temp 20 cm	°C	Min
12	Air temp. 20 cm	°C	Avg	35	Wind speed	ms^{-1}	Avg
13	Air temp.-screen	°C	Max	36	"	ms^{-1}	Max
14	"	PST	Time	37	"	PST	Time
15	R.H. screen	%	Max	38	Rainfall	mm	Total
16	"	PST	Time	39	Moisture block 0.5cm)	kΩ	Spot
17	Soil temp. 0.5cm)	°C	Max	40	5.0cm (grass	kΩ	Spot
18	5.0cm (grass	°C	Max	41	15.0cm)	kΩ	Spot
19	15.0cm)	°C	Max	42	0.5cm)	kΩ	Spot
20	0.5cm)	°C	Max	43	5.0cm (trees	kΩ	Spot
21	5.0cm (trees	°C	Max	44	15.0cm)	kΩ	Spot
22	15.0cm)	°C	Max	45	Vapour pressure	KPa	Avg
23	Air temp. 20cm	°C	Max	46	Vapour pressure def.	KPa	Max

COMMENTS:

APPENDIX V Computer file record form

COMPUTER FILE RECORD FORMAT Page __ of __

FILENAME:_____ DATE FROM:_____ TO:_____
LOCATION:_____

#	Variable	Type	Unit	#	Variable	Type	Unit
1				24			
2				25			
3				26			
4				27			
5				28			
6				29			
7				30			
8				31			
9				32			
10				33			
11				34			
12				35			
13				36			
14				37			
15				38			
16				39			
17				40			
18				41			
19				42			
20				43			
21				44			
22				45			
23				46			

COMMENTS:

COMPUTER FILE RECORD FORMAT Page 1 of 1

FILENAME: WL87DAY.WK1 DATE FROM: 87/3/14 TO: 87/12/31
LOCATION: EM.FIRE, Williams Lake

#	Variable	Type	Unit	#	Variable	Type	Unit
1	Date			24			
2	Solar rad.	Total	$MJm^{-2}d^{-1}$	25			
3	Air temp.-screen	Avg	°C	26			
4	Air temp.	Max	°C	27			
5	"	Time	PST	28			
6	Air temp.	Min	°C	29			
7	"	Time	PST	30			
8	R.H. screen	Max	%	31			
9	"	Time	PST	32			
10	Air temp. 20 cm	Avg	°C	33			
11	"	Max	°C	34			
12	"	Min	°C	35			
13	Wind speed	Avg	ms^{-1}	36			
14	"	Max	ms^{-1}	37			
15	"	Time	PST	38			
16	Rainfall	Total	mm	39			
17	Vapour pressure	Avg	kPa	40			
18	Vapour press. def.	Max	kPa	41			
19	"	Time	PST	42			
20	Battery voltage		V	43			
21				44			
22				45			
23				46			

COMMENTS:

APPENDIX VI Log sheet

SITE LOG - DATA LOGGER MAINTENANCE RECORD

LOCATION:_____ MODEL & S/N:_____

DATE:_____ TIME:_____

CLOCK *5: YEAR:_____ JD:_____ TIME:_____

DATA POINTERS *8: 1._____ 2._____

PREVIOUS END-OF-DATA POINTER:_____ OVERFLOW?:_____

DATA TRANSFER: TAPE:_____ COMPUTER:_____ GOOD TRANSFER?__

FILENAME:_____

SIGNATURES *B: 1._____ 2._____ 3._____

SCAN RATES: *1._____ *2._____ *3(CR21)_____

CURRENT READINGS *6:

1._____	11._____	21._____	31._____	41._____
2._____	12._____	22._____	32._____	42._____
3._____	13._____	23._____	33._____	43._____
4._____	14._____	24._____	34._____	44._____
5._____	15._____	25._____	35._____	45._____
6._____	16._____	26._____	36._____	46._____
7._____	17._____	27._____	37._____	47._____
8._____	18._____	28._____	38._____	48._____
9._____	19._____	29._____	39._____	49._____
10._____	20._____	30._____	40._____	50._____

COMMENTS:_____

_____

_____

_____

BATTERY V. OK?:_____ *0 LOG_____

SITE LOG - DATA LOGGER MAINTENANCE RECORD

LOCATION: EM Fire, Williams Lake MODEL & S/N: 21X -1221

DATE: 15 July, 1987 TIME: 0800 PST

CLOCK *5: YEAR: 87 JD: 196 TIME: 08:01

DATA POINTERS *8: 1. 7301 2. 17924

PREVIOUS END-OF-DATA POINTER: 7301 OVERFLOW?: No

DATA TRANSFER: TAPE: ✓ COMPUTER: _____ GOOD TRANSFER? Y

FILENAME: _____

SIGNATURES *B: 1. _____ 2. _____ 3. _____

SCAN RATES: *1. 10 sec *2. 10 sec *3(CR21) _____

CURRENT READINGS *6:

1. 486	11. 8.71	21. 42.0	31. _____	41. _____
2. 18.1	12. 3.42	22. 1221	32. _____	42. _____
3. 45.1	13. 0.89	23. 0.94	33. _____	43. _____
4. 28.9	14. 9.13	24. 12.3	34. _____	44. _____
5. 16.4	15. 2.01	25. _____	35. _____	45. _____
6. 13.0	16. 0.51	26. _____	36. _____	46. _____
7. 35.6	17. 2.64	27. _____	37. _____	47. _____
8. 20.5	18. 0	28. _____	38. _____	48. _____
9. 15.0	19. 10.1	29. _____	39. _____	49. _____
10. 21.7	20. 1.14	30. _____	40. _____	50. _____

COMMENTS: New battery installed 12.3V

Replaced silica gel

TD = 18.2°C, TW = 11.0°C, R.H. = 43%

storage gauge = 22mm

BATTERY V. OK?: 12.3V *0 LOG 12